SECTION 26 0573 - OVERCURRENT PROTECTIVE DEVICE COORDINATION STUDY

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and Division 26 specifications apply to this Section.

1.2 SUMMARY

A. This section includes electrical system and overcurrent protective device studies including:

1. Fault-current analysis.
2. Coordination study and device settings.
3. Arc-flash hazard analysis.

B. Related Sections include the following:

1. Division 26 Section "Static Uninterruptable power Supply"
2. Division 26 Section "Switchboards"
3. Division 26 Section "Static Transfer Switches"

1.3 ACTION SUBMITTALS

A. General: N/A

B. Product data: For computer software to be used to perform studies.

C. Product certificates: For coordination-study and fault-current analysis computer software programs, certifying compliance with IEEE 399.

D. Qualifications:

1. Submit evidence indicating individual and organization compliance with requirements indicated in "Quality Assurance" below.

E. Preliminary electrical system study: Submit for review before distribution equipment shop drawings have been approved, and before equipment order has been released to the manufacturer.

1. Submit a preliminary draft for review.
2. If formal completion of the study may delay the project schedule, AOC may approve use of the preliminary draft for ordering equipment.

3. If approved for use in ordering equipment, preliminary draft shall include sufficient study data to ensure that the selection of device ratings and characteristics will be satisfactory.

F. Final electrical system study:

1. Submit final report for review and record.
2. Incorporate changes resulting from deficiencies and corrections of preliminary draft report.

G. Reports:

1. Electrical system study report: Submit reports required above including the following items:

a. General report information: Scope, definitions, descriptions, assumptions, and other information necessary to properly interpret results of the report.
b. Tabulated summary comparing protective device ratings and calculated available fault-current levels.
c. Tabulated summary of protective device settings including circuit breaker, fuse, and relays.
d. Fault-current analysis calculations.
e. Selective coordination study overlay, plots of device time-current curves and relationship to other distribution system components.
f. Arc-flash hazard calculations including details of the incident energy and flash protection boundary calculations.
g. Recommendations for system improvements.
h. System one-line diagram.
i. Input and output data used for each component and for study calculations.

2. Inspection and testing report: Include certification of compliance with specified requirements, identify deficiencies, and recommend corrective action when appropriate.

a. Written report documenting the results of each site visit, submitted not more than ten days after each visit.
b. Test reports documenting the results of each test, submitted not more than ten days after test is completed.

1.4 CLOSEOUT SUBMITTALS

A. Submit final reports as electronic files in portable document format (.pdf) to the AOC. Submit program base files in file format compatible with Power Tools for Windows (SKM Systems Analysis, Inc.).

1.5 QUALITY ASSURANCE

A. Electrical system study shall be performed by one or more independent qualified organizations, and under the supervision and approval of a Registered Professional Engineer skilled in performing and interpreting the power system studies.

B. Qualifications of organization performing electrical system study: An entity experienced in the application of computer software used for studies, having performed successful studies of similar magnitude on electrical distribution systems using similar devices:

1. Registered Professional Engineer shall be a full-time employee of the equipment manufacturer or of an approved engineering firm.
2. Registered Professional Engineer shall have a minimum of five (5) years of experience in performing power system studies and registered in the state where the project is located.

C. Qualifications of computer based software: Widely available, complying with standards, guides, and codes as referenced above.

D. Comply with IEEE 399 for general study procedures.

E. Comply with IEEE 242 for short-circuit currents and coordination time intervals.

1.6 REFERENCES

A. Institute of Electrical and Electronics Engineers (IEEE):

1. IEEE 141 – Recommended Practice for Electric Power Distribution and Coordination of Industrial and Commercial Power Systems.
2. IEEE 241 – Recommended Practice for Electric Power Systems in Commercial Buildings.
3. IEEE 242 – Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems.
4. IEEE 399 – Recommended Practice for Industrial and Commercial Power System Analysis.
5. IEEE 1015 – Recommended Practice for Applying Low-Voltage Circuit Breakers Used in Industrial and Commercial Power Systems.
6. IEEE 1584 - Guide for Performing Arc-Flash Hazard Calculations.

B. American National Standards Institute (ANSI):

1. ANSI C57.12.00 – Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers.
2. ANSI C37.13 – Standard for Low Voltage AC Power Circuit Breakers Used in Enclosures.
3. ANSI C37.010 – Standard Application Guide for AC High Voltage Circuit Breakers Rated on a Symmetrical Current Basis.
4. ANSI C37.41 – Standard Design Tests for High Voltage Fuses, Distribution Enclosed Single-Pole Air Switches, Fuse Disconnecting Switches and Accessories.

C. National Fire Protection Association (NFPA):

1. NFPA 70 – National Electrical Code, latest edition.
2. NFPA 70E – Standard for Electrical Safety in the Workplace.

D. Occupational Safety and Health Administration (OSHA):
1. OSHA 29 Code of Federal Regulations (CFR) Part 1910, Subpart S.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Computer Software – Subject to compliance with requirements, utilize product by SKM Systems Analysis, Inc. (Basis of Design).

2.2 COMPUTER SOFTWARE REQUIREMENTS

A. Comply with IEEE 399.

B. Computer software program shall be capable of performing fault-current analysis of project electrical distribution system.

C. Computer software program shall be capable of plotting and diagramming time-current characteristic curves as part of its output. Computer software program shall report device settings and ratings of all overcurrent protective devices and shall demonstrate selective coordination by computer-generated, time-current coordination plots.

D. Computer software program shall be capable of performing arc fault hazard analysis using equations as established by IEEE 1584 and requirements presented in NFPA 70E, Annex D.

E. Software shall include a comprehensive equipment library of manufacturer-based and IEEE / ANSI based equipment to accurately model the electrical distribution system.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine project submittals for compliance with electrical distribution system requirements outlined on the drawings and in electrical specification sections.

3.2 SYSTEM DATA COLLECTION

A. The AOC shall furnish all data required to perform the power system studies. The Engineer performing the fault analysis, protective device coordination, and arc flash hazard analysis studies shall furnish the AOC with a listing of required data immediately after award of the contract.

B. If applicable, include fault contribution of existing motors and equipment in the study. The AOC shall provide the required existing equipment data, if necessary, to satisfy the study requirements.

C. The Engineer performing the studies shall gather and tabulate input data necessary to support each study including the following:

1. Product data for each component of the electrical distribution system.
2. Utility available fault contribution and impedance values.
3. Drawings, one-line, and riser diagrams showing system configuration, equipment designations, feeder lengths, and other applicable system characteristics.

3.3 SYSTEM FAULT CURRENT ANALYSIS

A. Calculate the maximum available short-circuit momentary current and interrupting duties in amperes rms symmetrical for electrical power distribution system components. The calculation shall be performed for current immediately after initiation and for a three-phase bolted fault at each of the following locations:

1. Electric utility’s supply termination.
2. Medium-voltage switchgear.
3. Medium-voltage network transformers and network protector terminals.
4. Low-voltage switchgear.
5. Switchboards.
6. Distribution panelboards.
7. Branch circuit panelboards.
8. Generator output terminals.
9. Automatic transfer switch terminals.
10. Other components listed on riser and one-line diagrams.

B. Study the project’s electrical distribution system from normal and alternate power sources throughout electrical distribution system. Where system configuration allows multiple switching and operation arrangements through paralleled sources, tie-breakers, or closed-transition switches, include study that results in maximum fault conditions.

C. For grounded systems, provide a bolted line-to-ground fault current study for areas as defined above for the three-phase, bolted fault, short-circuit study.

D. Calculations to verify interrupting ratings of overcurrent protective devices shall comply with IEEE 14, IEEE 241, and IEEE 242.

E. Study Report:

1. Input Data: Gather and provide the following input data, in tabular or graphic form, used to perform fault calculations and other studies in this Section.

   a. Utility three-phase and line-to-ground available contribution with associated X/R ratios.
   b. Short-circuit reactance of rotating machines with associated X/R ratios.
   c. Cable type, construction, size, quantity per phase, length, impedance and conduit type.
   d. Transformer primary & secondary voltages, winding configurations, kVA rating, impedance, and X/R ratio.
   e. Reactor inductance and continuous ampere rating.

2. Methods and Assumptions: Indicate calculation methods and assumptions that may have been used to perform analysis.
3. Results: Show calculated X/R ratios and equipment interrupting rating (1/2-cycle) fault currents on electrical distribution system diagram. Provide the following:

   a. Source fault impedance and generator contributions
   b. X/R ratios
   c. Asymmetry factors
   d. Motor contributions
   e. Short circuit KVA
   f. Symmetrical and asymmetrical fault currents

4. Equipment evaluation and conclusions:

   a. Verify interrupting ratings and withstand ratings are equal to or higher than calculated fault current levels.
   b. Verify adequacy of phase conductors at maximum three-phase, bolted fault currents.
   c. Verify adequacy of equipment grounding conductors and grounding electrode conductors for grounded systems at maximum ground-fault currents.

5. Recommendations: List recommendations for equipment with inadequate ratings. Notify AOC, in writing, of existing equipment improperly rated for the calculated available fault current of the system.

3.4 SYSTEM COORDINATION STUDY

A. Perform coordination study using approved computer software program. Prepare a written and graphical report using results of fault current study and proposed protective devices and system distribution components. Comply with IEEE 399.

B. Coordination Curves: Prepared to determine settings of overcurrent protective devices to achieve selective coordination. Graphically illustrate that adequate time separation exists between devices installed in series using time-current curves plotted on log-log scale graphs.

C. Prepare separate sets of curves to adequately demonstrate full system coordination. Include the following equipment on plotted coordination curves:

1. Electric utility’s overcurrent protective devices.
2. Medium-voltage equipment overcurrent relays.
3. Medium- and low-voltage fuses including manufacturer’s minimum melt, total clearing, tolerance, and damage bands.
4. Low-voltage equipment circuit breaker trip devices, including manufacturer’s tolerance bands.
5. Transformer full-load current, magnetizing inrush current, and ANSI through-fault protection curves.
6. Conductor damage curves.
7. Ground-fault protective devices.
8. Significant motor starting characteristics and motor damage points.
9. Significant generator short-circuit decrement curve and generator damage point.
10. Largest feeder circuit breaker for motor control center and distribution panelboards.

D. Recommended Device Settings: Prepare a tabulated summary of recommended device settings for system adjustable protective devices. Include the following information:

1. Device tags.
2. Phase and Ground Relays:

   a. Current transformer ratios
   b. Current settings
   c. Time settings
   d. Instantaneous settings
   e. Specialty non-overcurrent device settings
   f. Recommendations for improved system coordination

3. Circuit breakers:

   a. Sensor and plug ratings, where applicable.
   b. Adjustable pickups and time delays (long time, short time, ground)
   c. Adjustable time-current characteristic
   d. Adjustable instantaneous pickup
   e. Recommendations for improved system coordination

4. Fuses:

a. Current rating
b. Type

3.5 SYSTEM ARC FLASH HAZARD ANALYSIS

A. The arc flash hazard analysis shall be performed according to the IEEE 1584 equations that are presented in NFPA 70E, Annex D.

B. The flash protection boundary and the incident energy shall be calculated at all significant locations in the electrical distribution system (such as switchboards, switchgear, motor-control centers, panelboards, busway and splitters) where work could be performed on energized parts.

C. The Arc-Flash Hazard Analysis shall include electrical equipment locations where work such as examination, adjustment, service, or maintenance could be performed on energized parts.

D. Safe working distances shall be based upon the calculated arc flash boundary considering incident energy of 1.2 cal/cm2.

E. When appropriate, the short circuit calculations and the clearing times of the phase overcurrent devices will be retrieved from the short-circuit and coordination study model. Ground overcurrent relays should not be taken into consideration when determining the clearing time when performing incident energy calculations.

F. The short-circuit calculations and the corresponding incident energy calculations for multiple system scenarios must be compared and the greatest incident energy must be uniquely reported for each equipment location. Calculations must be performed to represent the maximum and minimum contributions of fault current magnitude for all normal and emergency operating conditions. The minimum calculation will assume that the utility contribution is at a minimum and will assume a minimum motor contribution (all motors off).

Conversely, the maximum calculation will assume a maximum contribution from the utility and will assume the maximum amount of motors to be operating. Calculations shall take into consideration the parallel operation of synchronous generators with the electric utility, where applicable.

G. The incident energy calculations must consider the accumulation of energy over time when performing arc flash calculations on buses with multiple sources. Iterative calculations must take into account the changing current contributions, as the sources are interrupted or decremented with time. Fault contribution from motors and generators should be decremented as follows:

1. Fault contribution from induction motors should not be considered beyond 3-5 cycles.

2. Fault contribution from synchronous motors and generators should be decayed to match the actual decrement of each as closely as possible (e.g. contributions from permanent magnet generators will typically decay from 10 per unit to 3 per unit after 10 cycles).

H. For each equipment location with a separately enclosed main device (where there is adequate separation between the line side terminals of the main protective device and the work location), calculations for incident energy and flash protection boundary shall include both the line and load side of the main breaker.

I. When performing incident energy calculations on the line side of a main breaker (as required per above), the line side and load side contributions must be included in the fault calculation.

J. Mis-coordination should be checked amongst all devices within the branch containing the immediate protective device upstream of the calculation location and the calculation should utilize the fastest device to compute the incident energy for the corresponding location.

K. Arc Flash calculations shall be based on actual overcurrent protective device clearing time. Maximum clearing time will be capped at 2 seconds based on IEEE 1584. Where it is not physically possible to move outside of the flash protection boundary in less than 2 seconds during an arc flash event, a maximum clearing time based on the specific location shall be utilized.

L. Incident energy and flash protection boundary calculations.

1. Arcing fault magnitude
2. Device clearing time
3. Duration of arc
4. Arc flash boundary
5. Working distance
6. Incident energy
7. Hazard Risk Category
8. Recommendations for arc flash energy reduction

3.6 ARC FLASH WARNING LABELS

A. After the Arc Flash Hazard Analysis the Contractor shall provide a 3.5 in. x 5 in. thermal transfer type label of high adhesion polyester for each work location analyzed.

B. All labels will be based on recommended overcurrent device settings and will be provided after the results of the analysis have been presented to the Architect and after any system changes, upgrades or modifications have been incorporated in the system.

C. The label shall include the following information, at a minimum:

1. Location designation
2. Nominal voltage
3. Flash protection boundary
4. Hazard risk category
5. Incident energy
6. Working distance
7. Engineering report number, revision number and issue date

D. Labels shall be machine printed, with no field markings.

E. Arc flash labels shall be provided in the following manner and all labels shall be based on recommended overcurrent device settings.

1. For each 600V, 480V, and applicable 208V panelboard, one arc flash label shall be provided.
2. For each motor control center, one arc flash label shall be provided.
3. For each low-voltage switchboard, one arc flash label shall be provided.
4. For each switchgear, one flash label shall be provided.
5. For medium voltage switches one arc flash label shall be provided.

3.7 ARC FLASH TRAINING

A. The equipment vendor shall train personnel of the potential arc flash hazards associated with working on energized equipment (minimum of 4 hours). Maintenance procedures in accordance with the requirements of NFPA 70E, shall be provided in the equipment manuals. The training shall be certified for continuing education units (CEUs) by the International Association for Continuing Education Training (IACET).

3.8 FIELD QUALITY CONTROL

A. Field Adjustment: Adjust relay and protective device settings according to the recommended settings table provided by the coordination study. Field adjustments to be completed by the engineering service division of the equipment manufacturer under the Startup and Acceptance Testing contract portion.

B. Make minor modifications to equipment as required to accomplish conformance with short circuit and protective device coordination studies.

C. Notify Architect in writing of any required major equipment modifications.

END OF SECTION 26 0573